

TraitsCape: Understanding the role of microrefugia in buffering fynbos from global change

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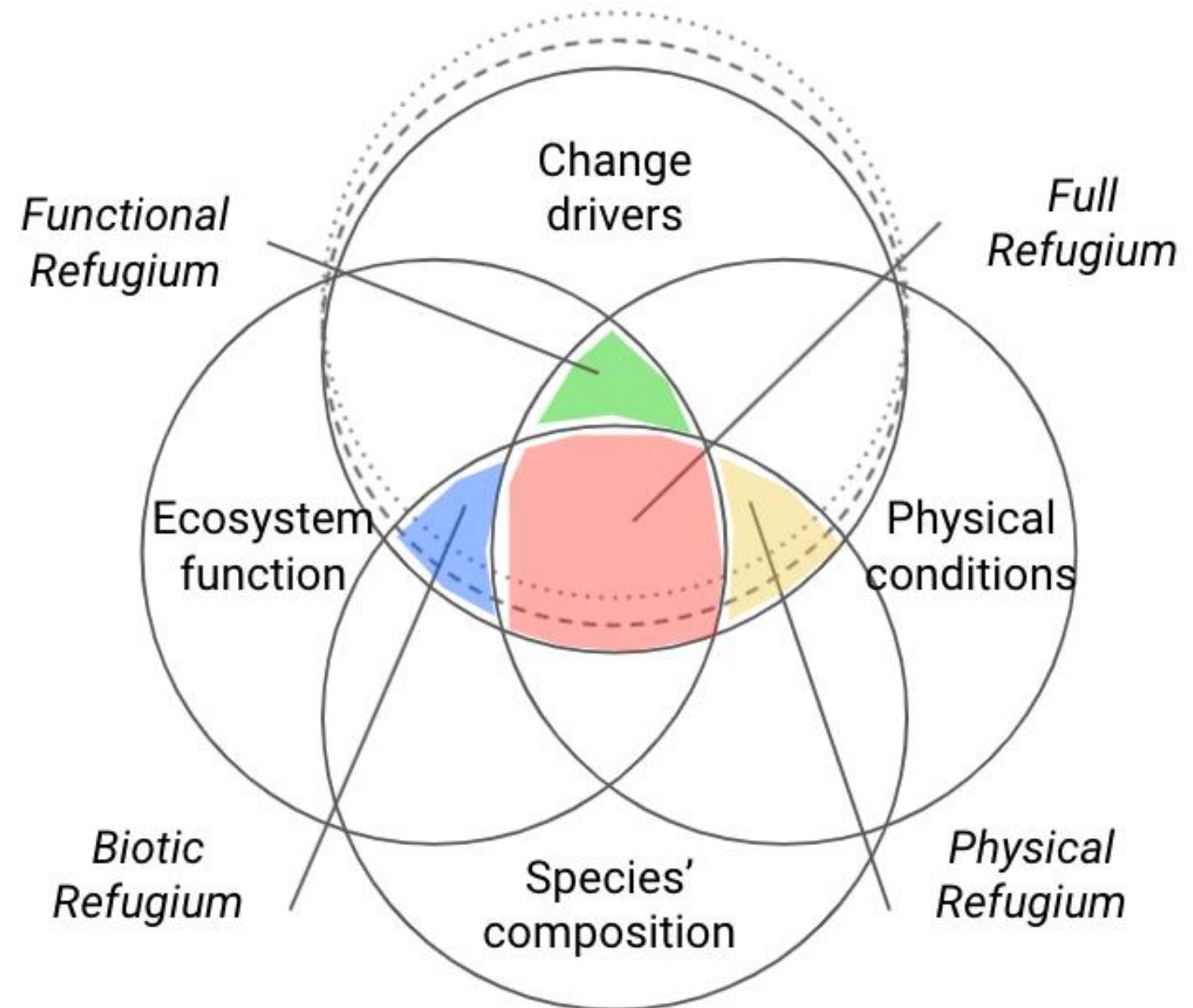
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Nicola van Wilgen SANParks

Refugia

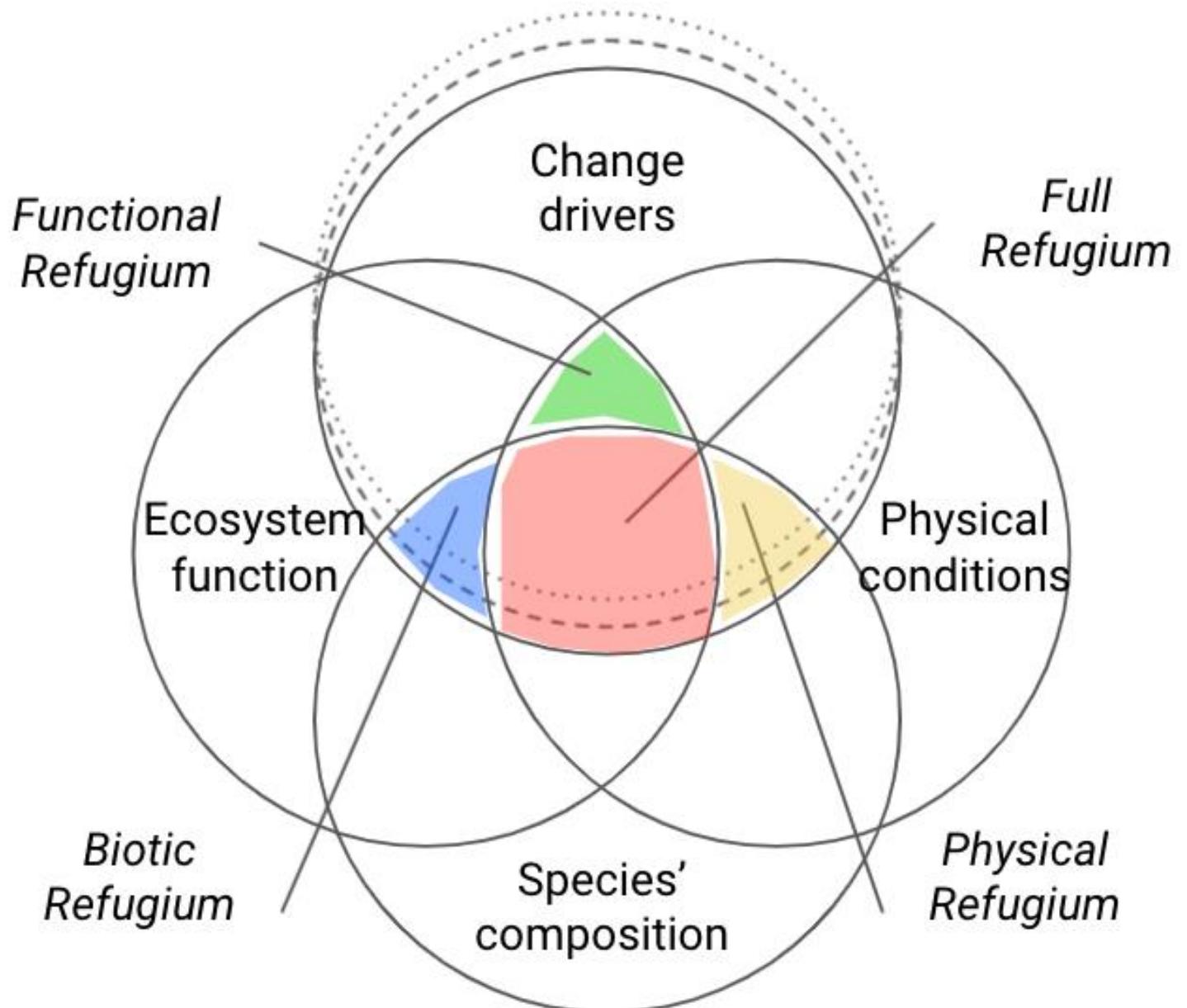


Refugia

When are fynbos communities likely to be resilient to change?

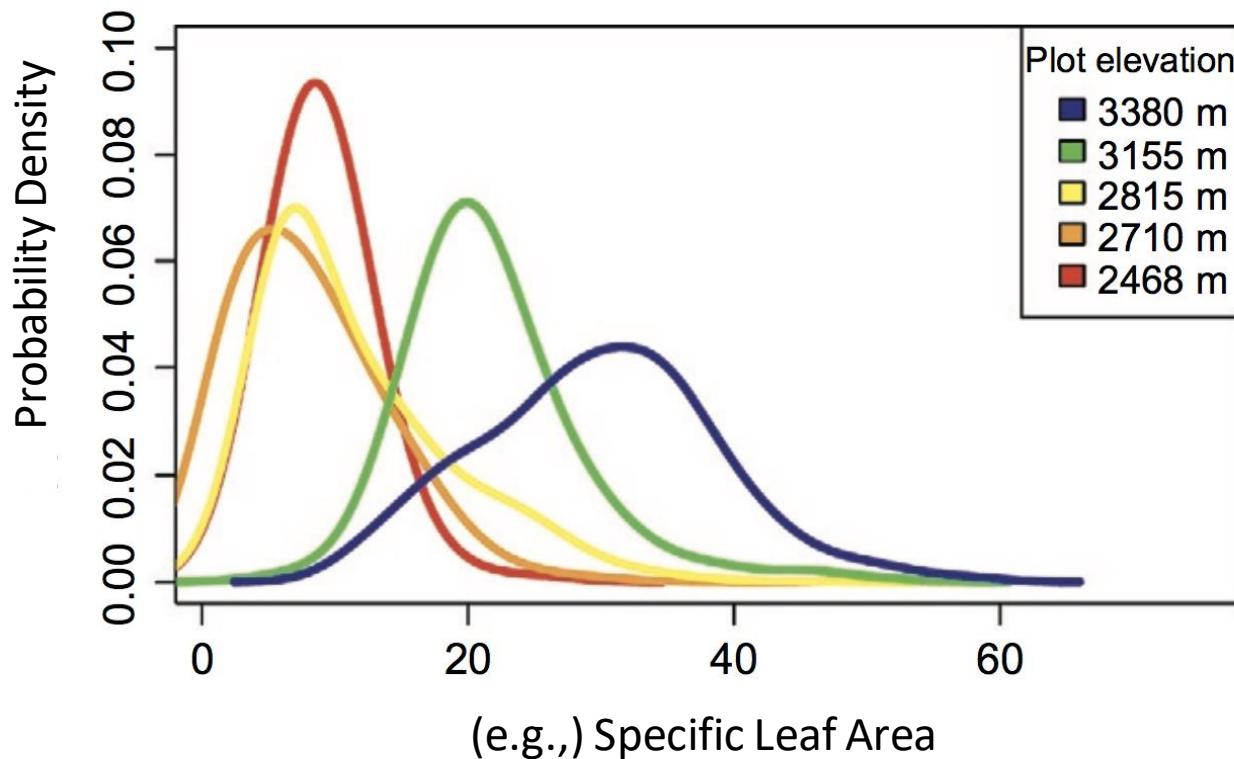
Will physical microrefugia maintain existing fynbos communities?

Will shifting abundance or immigration provide resilience in ecosystem function despite species composition change?



Trait Driver Theory

A general theory for trait-based ecology that can scale from individuals, to communities, and to ecosystems



Enquist et al. Adv. Ecol. Research 2015
Merow and Enquist, In prep

Dynamics of community trait moments

Total biomass

$$dC_T/dt = C_T[f(\bar{z}) + f^{(2)}(\bar{z})M_2 + f^{(3)}(\bar{z})M_3 + \dots] + I \quad (6)$$

Trait mean

$$d\bar{z}/dt = f^{(1)}(\bar{z})M_2 + f^{(2)}(\bar{z})M_3 + \dots + (I/C_T)(\bar{z}_I - \bar{z}) \quad (7)$$

Trait Variance

$$dV/dt = dM_2/dt = f^{(1)}(\bar{z})M_3 + f^{(2)}(\bar{z})(M_4 - M_2^2) + \dots + (I/C_T)[(\bar{V}_I - V) + (\bar{z}_I - \bar{z})^2] \quad (8)$$

Trait Skew

$$dS/dt = dM_3/dt = 3f^{(1)}(\bar{z})(M_4 + SV/B_T) + (I/C_T)[\dots] \quad (9)$$

f describes the per capita growth rate

M describes moments of the trait distribution

Turelli and Barton 1991

Norberg et al. 2001

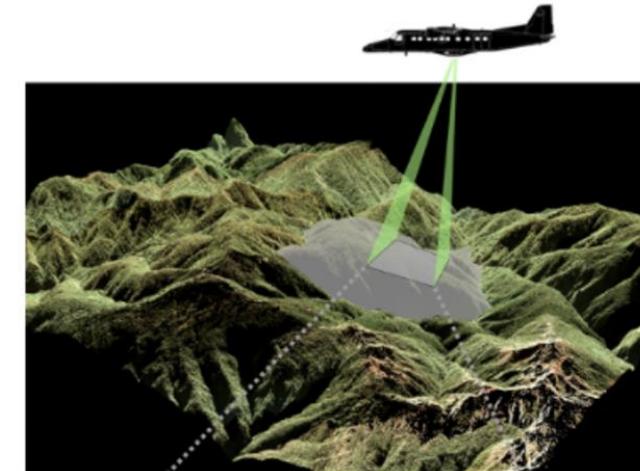
Savage et al. 2007

Enquist et. al 2015

Trait Moment Dynamics

Growth function

Total biomass



$$+ f^{(2)}(\bar{z})M_2 + f^{(3)}(\bar{z})M_3 + \dots] + I \quad (6)$$

Trait mean

$$+ f^{(2)}(\bar{z})M_3 + \dots + (I/C_T)(\bar{z}_I - \bar{z}) \quad (7)$$

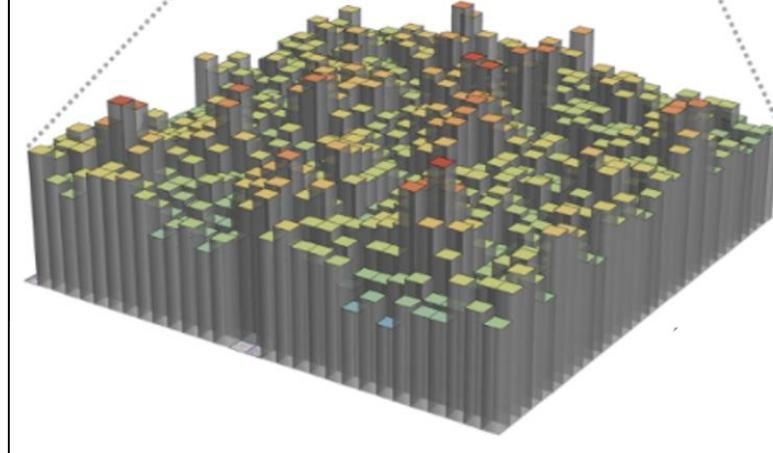
Trait Variance

$$(\bar{z})(M_4 - M_2^2) + \dots + (I/C_T)[(\bar{V}_I - V) + (\bar{z}_I - \bar{z})^2] \quad (8)$$

Trait Skew

$$3f^{(1)}(\bar{z})(M_4 + SV/B_T) + (I/C_T)[..] \quad (9)$$

Can parameterize
with *high
resolution* remote
sensing pixels



Trait Moment Dynamics

Growth function

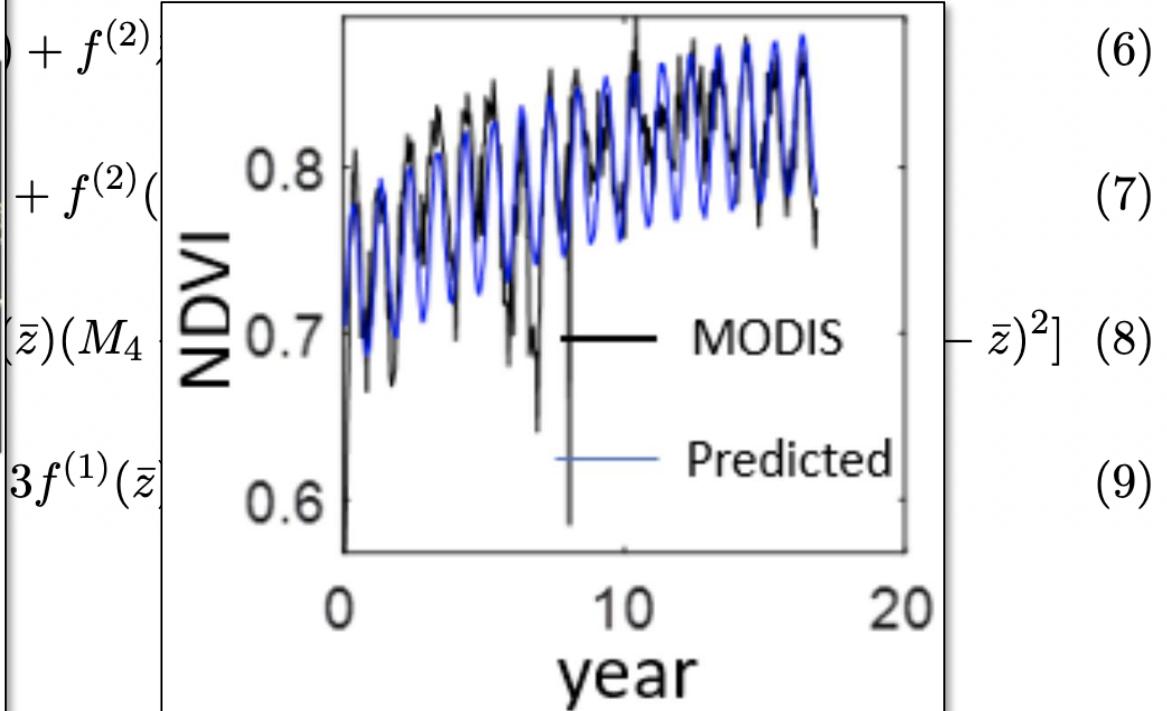
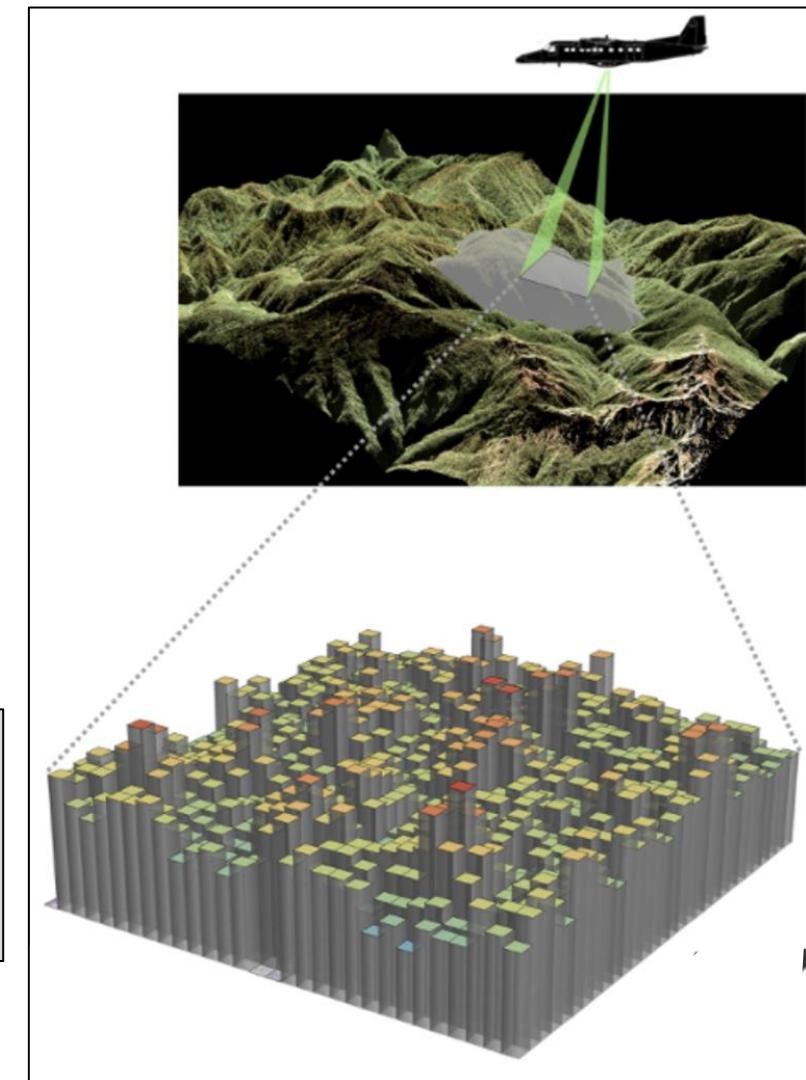
Total biomass

Trait mean

Trait Variance

Trait Skew

Can parameterize
with *high
resolution* remote
sensing pixels



And a biomass growth as model
(Wilson et al. 2010)

Adding more trait structure....

$$\text{recruit trait : } r_q(q'|q, \text{env}) \sim \mathcal{F}(f(q, \text{env}), \epsilon_{q2})$$

$$\text{growth : } g(x'|x, q, \text{env}) \sim \mathcal{F}(f(x, q, \text{env}), \sigma_g^2)$$

$$\text{survival : } s(x, q, \text{env}) = f(x, q, \text{env})$$

$$\text{recruits : } r(x, q, \text{env}) = f(x, q, \text{env})$$

$$\text{recruit size : } r_x(x'|x, q, \text{env}) \sim \mathcal{F}(f(x, q, \text{env}), \sigma_r^2)$$

$$n_{t+1}(x', q') = \int_{\Omega_z} \int_{\Omega_q} K(x', q'|x, q, \text{env}) n_t(x, q) dx dq + I(x', q', \text{env})$$

$$K(x', q'|x, q, \text{env}) = P(z', q'|x, q, \text{env}) + F(z', q'|x, q, \text{env})$$

$$P(x', q'|x, q, \text{env}) = s() g() t(); \quad F(x', q'|x, q, \text{env}) = r() r_x() r_q()$$

$$I(x', q'|env) \sim \mathcal{F}(\text{metacommunity}(x, q), \text{env})$$

$$N(x, q) = \sum_i n_i(x, t)$$

$$K^*(x', q'|x, q, \text{env}) = \sum_i K_i(x, t, \text{env})$$

$$\text{biomass} = \int_{\Omega_z} \int_{\Omega_q} N(x, q) dx dq$$

$$\text{NPP} = \lambda_1 \int_{\Omega_z} \int_{\Omega_q} N(x, q) dx dq$$

$$\text{time to recovery} = t_z = \log(z)/\log(\lambda_1/|\lambda_2|)$$

$$\text{trait life expectancy} = \eta = \sum_j^J (\mathbf{I} - \mathbf{P})_{i,j}^{-1}$$

Decorative

Traits ~ Environment

Individual
Demography ~ Traits

Population Dynamics ~
Individual Demography

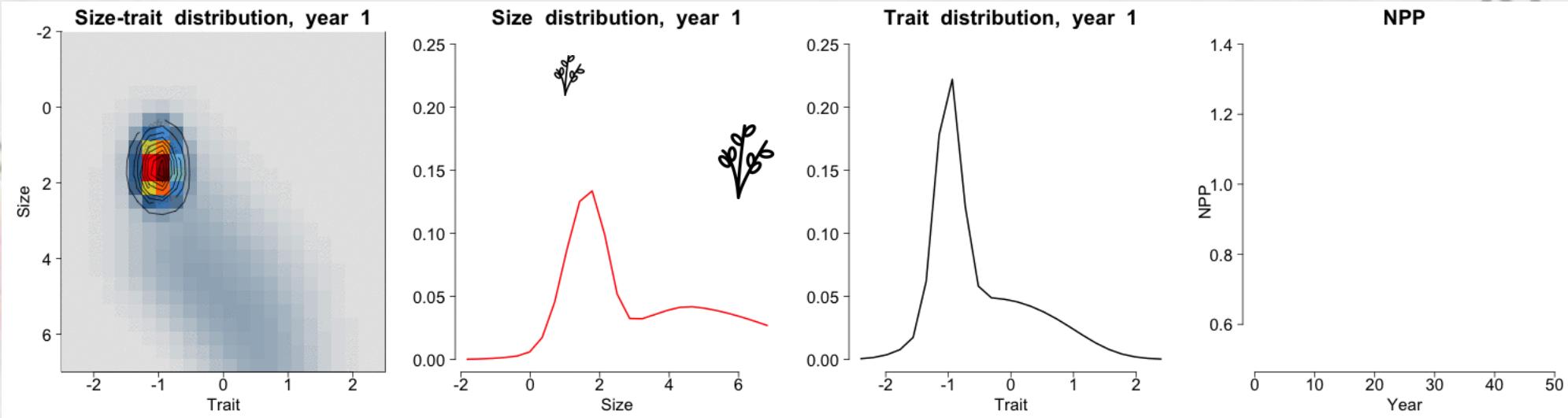
Community Dynamics ~
Population Dynamics

Ecosystem Function ~
Community Dynamics

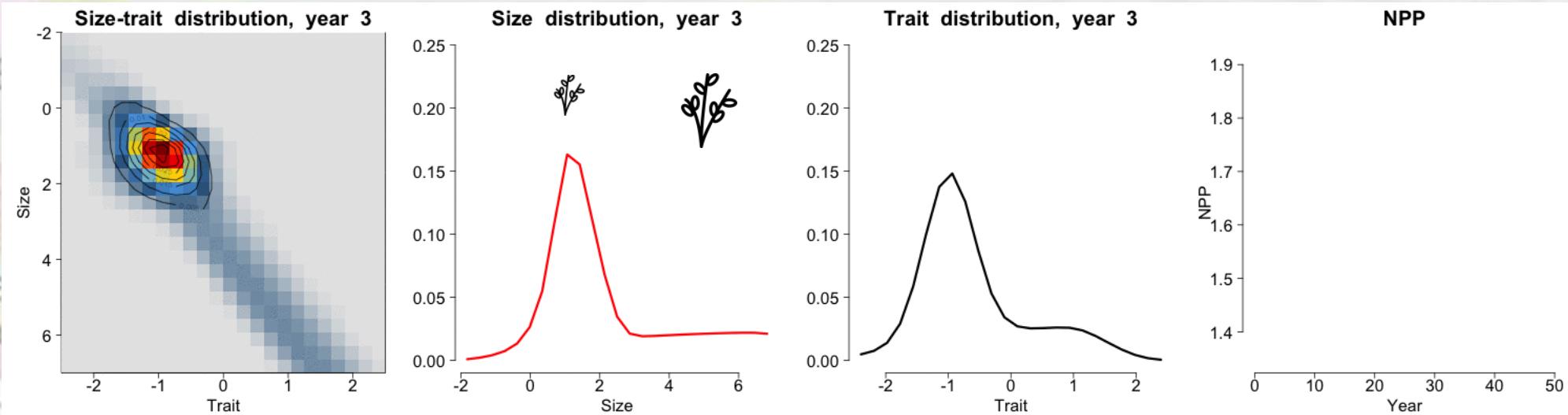
Immigration is needed for resilience



Scenario 1:
Local Adaptation,
No dispersal

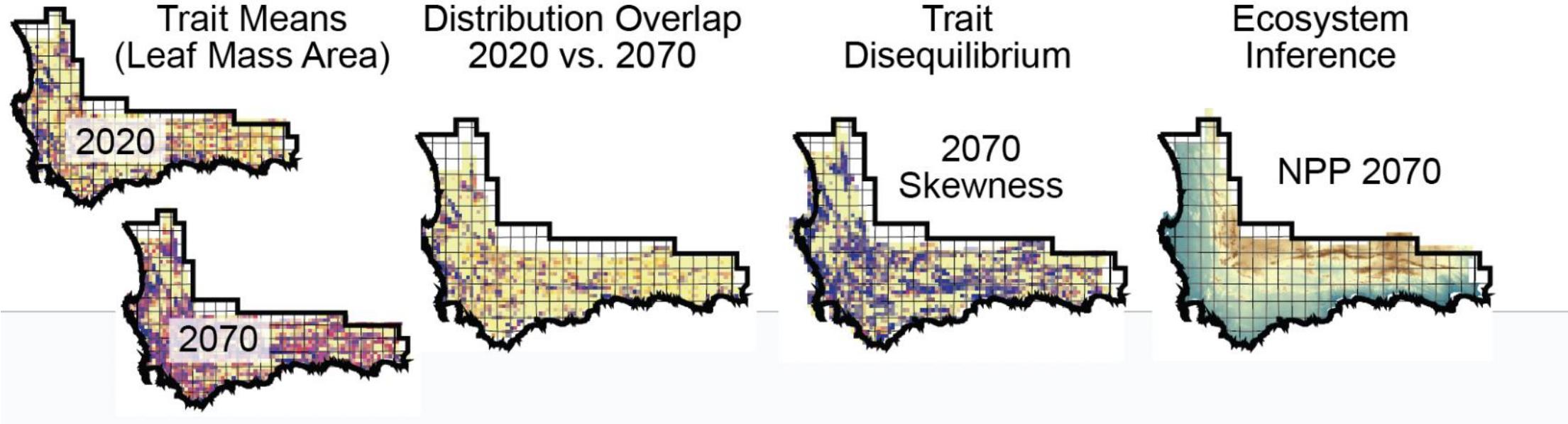


Scenario 2:
Immigration of
traits better
suited for new
climate



200 km

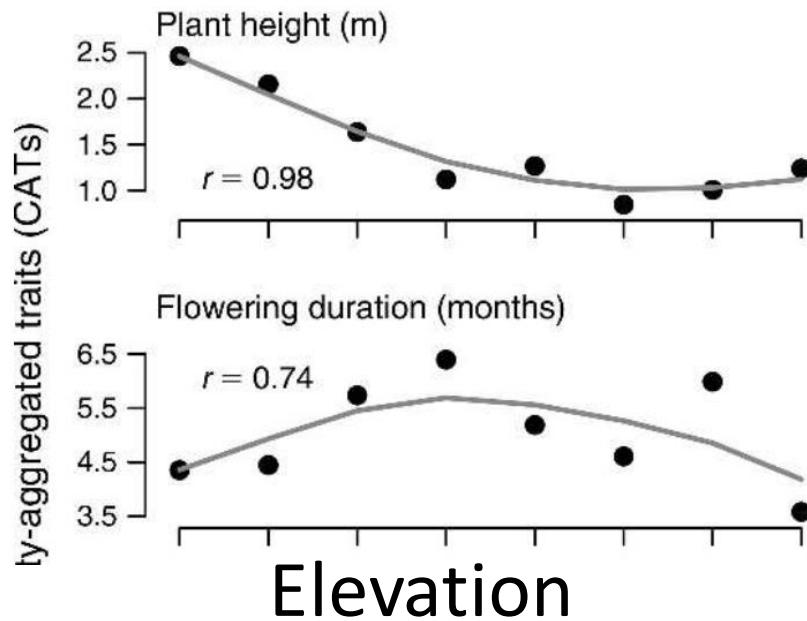
Products



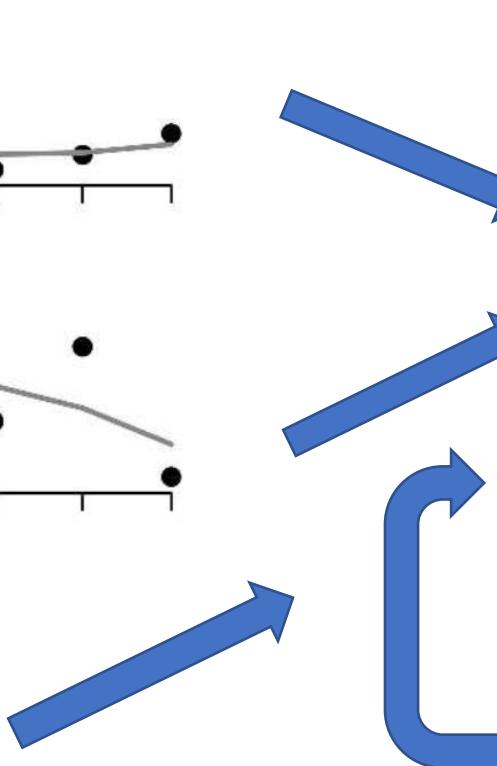
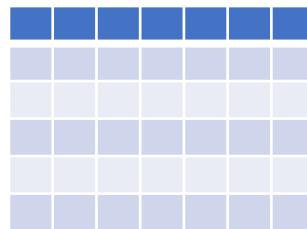
(Possibly only along flight paths, but we'll try using environmental covariates to extend to the CFR)

Recovering species composition from trait distributions

Community Trait

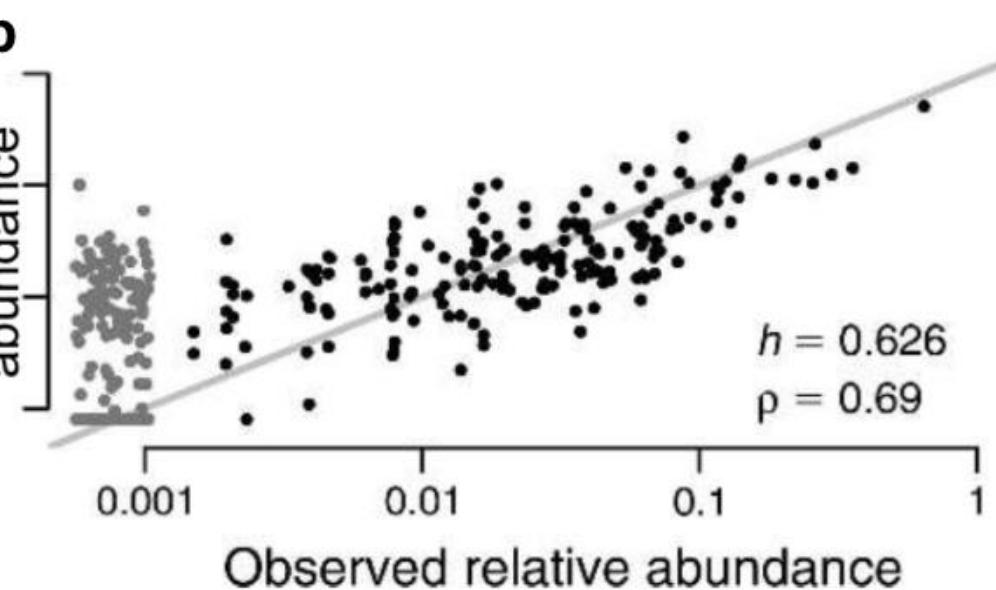


Elevation

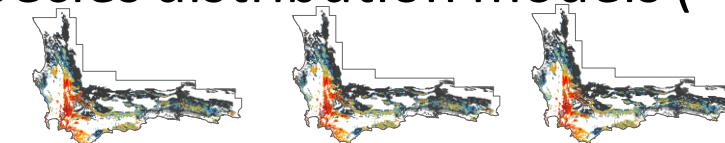


Predicted relative abundance

b



Species distribution models (~6k plants)



Merow et al 2011

Thanks!

Pep Serra-Diaz

Mark Urban

Xinyi Shen

Pep Serra-Diaz

Jasper Slingsby

Wendy Foden

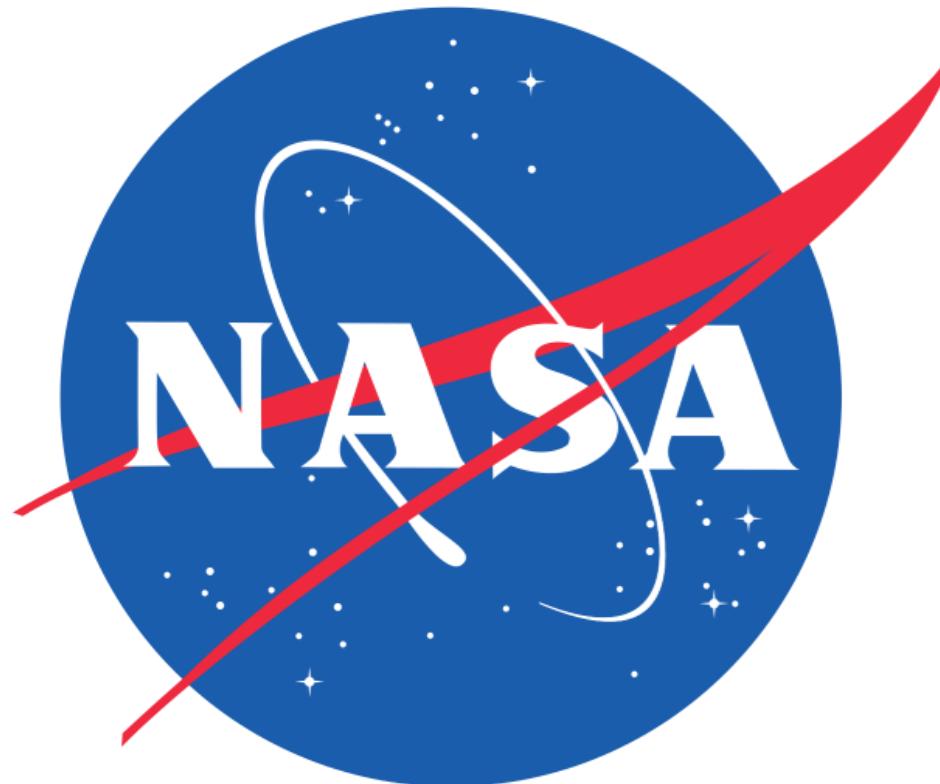
Nicola van Wilgen

Brian Enquist

Manos Anagnostou

Adam Wilson

Questions?



Bonus slides below

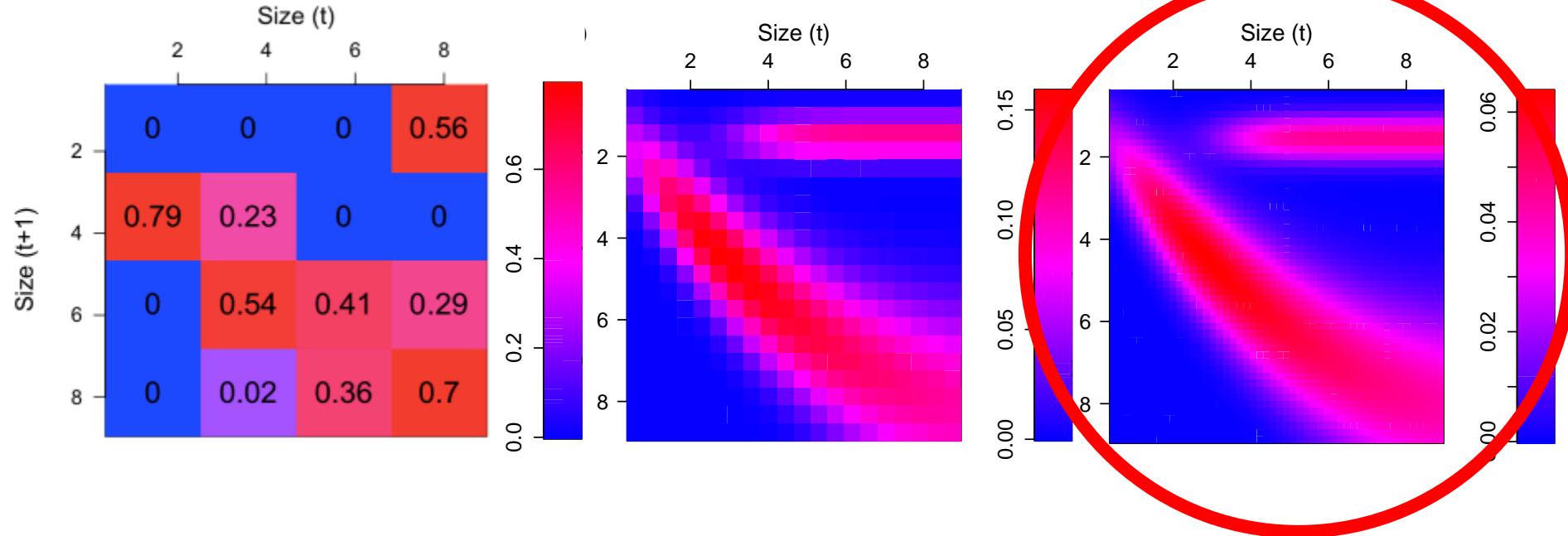
Trait Driver Theory

Moment of Community Trait Distribution, $C(z)$	Predictions for Rate of Community Response to a Changing Environment	Predicted Ecosystem Effects
I. Mean	<ul style="list-style-type: none"> (a) Will shift if environmental change alters value of z_{opt} and time scales are not too rapid and oscillatory (b) Lags z_{opt} by an amount that depends on rate of change in environment, rates of immigration, and the forces that influence the variance 	<ul style="list-style-type: none"> (i) Will shift productivity according to form of growth equation, f
II. Variance	<ul style="list-style-type: none"> (a) Decreases with strong filtering (b) Decreases due to competitive exclusion by individuals with trait z_{opt} (c) Can increase with increased immigration, competitive niche displacement, and/or temporal variation in z_{opt} 	<ul style="list-style-type: none"> (i) Increased variance implies lower productivity for fixed or stable environment (ii) Increased variance accelerates community response to environmental changes
III. Skewness	<ul style="list-style-type: none"> (a) Skewness values $>$ or $<$ 0 can reflect a lag between \bar{z} and z_{opt} and a rapidly changing community due to an environmental driver or extreme limit to a trait value (b) Increases in skewness can indicate a response to rapid environmental changes or the importance of rare species advantages in local coexistence 	<ul style="list-style-type: none"> (i) Depending upon kurtosis and variance value, productivity should be reduced compared with a community with similar variance but skewness equal to zero

Decorative

Trait distribution moments scale with ecosystem function!

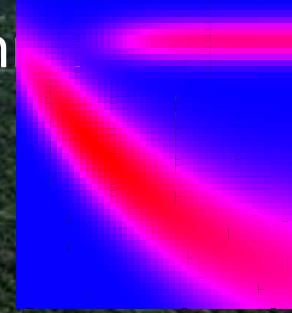
A step further with Integral Projection Models



Apply to communities,
rather than populations

Ecosystem Predictions

Reinterpreting population statistics in terms of community and ecosystem statistics



Ecosystem Quantity	Metric
Net Primary Productivity	Dominant right eigenvalue
Trait distributions	Dominant right eigenvector
Resilience	Damping Ratio
Duration of successional stages	Life Expectancy
Sensitivity/Elasticity	Eigenvectors